VOL. 5 NO. 3 MARCH 1954

Technical Notes ON BRICK & TILE CONSTRUCTION

STRUCTURAL CLAY PRODUCTS INSTITUTE

A. I. A. FILE NO. 5-F

REINFORCED BRICK MASONRY — III

(An Introduction to Reinforced Brick Masonry Design)

INTRODUCTION

Tests indicate that the structural performance of reinforced brick masonry is analogous to that of reinforced concrete and that the formulae used in the calculation of stresses and deflections in reinforced concrete flexural members can be used in calculations for similar RBM members. Both types of construction perform like homogeneous beams in that all relations of load and moment to deflection and stress are linear over ranges of loading well past design loads.

Since the flexure formulae for RBM are identical to those derived for reinforced concrete design and may be found in any standard text book (also Appendix B of Reinforced Brick Masonry and Lateral Force Design by Plummer and Blume), they will not be repeated in this bulletin. It is sufficient to say here that RBM design is based on the straight line theory of stress distribution (see Fig. 1) which, in turn, is based on the following assumptions:

1. The unit steel stress is within the elastic limit.
2. Plane sections before bending are assumed to remain plane sections after bending.
3. Unit stress deformations in the masonry at any given section of the beam are considered to vary as the ordinates to a straight line, starting from zero and increasing directly with the distance from the neutral axis.
4. Tension in the masonry is neglected.
5. Bond between steel and masonry is perfect—no "slipping" of steel occurs.

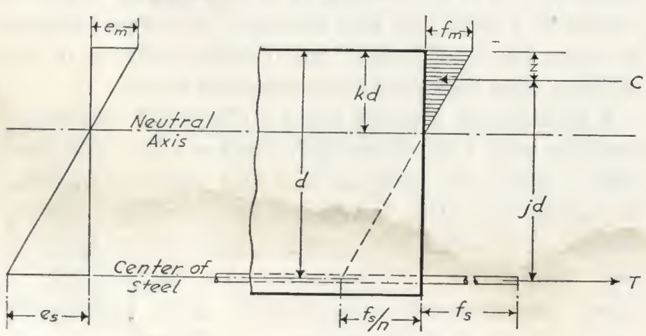

Fig. 1

TABLE 1

ALLOWABLE WORKING STRESSES FOR REINFORCED MASONRY

Stress	Allowable Stress psi	
f_m Compression—axial		
Walls— with minimum reinforcement (1)	0.20 f'_m	
Columns and walls in which reinforcement is designed, placed and anchored as in columns	(2)	
f_m Compression—flexural	0.33 f'_m	
v_m Shear—No web reinforcement	50 psi (3)	
v Shear—with web reinforcement	150 psi (3)	
f_m Bearing	0.25 f'_m	
E_m Modulus of Elasticity	1000 f'_m	
E_v Modulus of rigidity in shear	400 f'_m	
Bond	Mortar or A-1 psi	Grout A-2 psi
u Plain bars	80	60
u Deformed bars (ASTM A305-)	160	120

(1) Walls reinforced with an area of steel not less than 0.002 times the cross-sectional area of the wall, not more than ⅔ of which may be used in either direction. Vertical spacing of bars cannot exceed 36 in.

(2) See Section 308(c), page 121 of Reinforced Brick Masonry and Lateral Force Design.

(3) A-1 or A-2 mortar and grout.

WORKING STRESSES FOR MASONRY

Recommended working stresses for reinforced masonry are shown in Table 1. The term f'_m, used in determining the working stresses, denotes the compressive strength of the masonry at 28 days, unless otherwise specified. The value of f'_m is determined by one of the following methods:

For Solid Masonry. The compressive strength (f'_m) of solid masonry may be determined by compression tests on prisms built of similar materials under the same conditions and, insofar as possible, with the same bonding arrangements as for the structure. The prisms should have an h/d ratio of not less than 2 and shall be at least 16 in. high. If the h/d ratio differs from 2, the value of f'_m shall be determined by applying a correction factor to the compressive strength of the specimens. These correction factors are:

h/d	1.5	2.0	2.5	3.0	4.0	5.0	6.0
Correction factor	0.86	1.0	1.11	1.2	1.33	1.43	1.5

A. I. A. FILE NO. 5-F

If it is not convenient or possible to establish f'_m by preliminary tests, an assumed value of f'_m may be used. It shall not exceed 60 per cent of the compressive strength of the units (psi) when Type A-1 mortar is used and 45 per cent of the compressive strength when Type A-2 mortar is used. In each case this assumed value of f'_m shall not exceed 2000 psi nor 1500 psi, respectively.

For Hollow Masonry. The compressive strength f'_m of hollow masonry can likewise be determined by preliminary tests on prisms built of similar materials, under the same conditions and, insofar as possible, with the same bonding arrangements as for the structure. Such test prisms shall be 8 x 8 in. in plan and 16 in. high or 8 x 16 in. in plan and 16 in. high. The hollow cores shall not be filled with grout. The value of f'_m shall be computed by dividing the ultimate compressive load by the net area of the hollow masonry units used.

When it is not possible to establish the strength of the hollow masonry by means of preliminary tests, an assumed value of f'_m can be used not exceeding 60 per cent of the compressive strength of the units (psi on net area) when Type A-1 mortar is used and not more than 45 per cent when Type A-2 mortar is used. Such assumed values of f'_m shall not exceed a value of 1500 psi nor 1000 psi, respectively.

WORKING STRESSES FOR STEEL

The allowable stresses in the steel reinforcement used in RBM should not exceed the following:

f_s Unit tensile stress in longitudinal reinforcement and f_v unit tensile stress in web reinforcement:	
Structural grade steel bars	18,000 psi
Structural steel shapes	18,000 psi
Intermediate grade and hard-grade steel bars	20,000 psi
f_s Compression in column verticals	
Intermediate grade steel bars	16,000 psi
Hard-grade steel bars	20,000 psi

DESIGN DIMENSIONS

The designer in RBM does not have quite the freedom in determining wall thicknesses, beam depths and widths as he does when designing in reinforced concrete. The actual wall thickness, beam width, etc., are determined in the final analysis by the sizes of the units and the thickness of mortar joints, together with the size and location of the reinforcement.

For example, mortar joints, in which bars larger than ¼ in. in diameter are placed, must be ½ in.

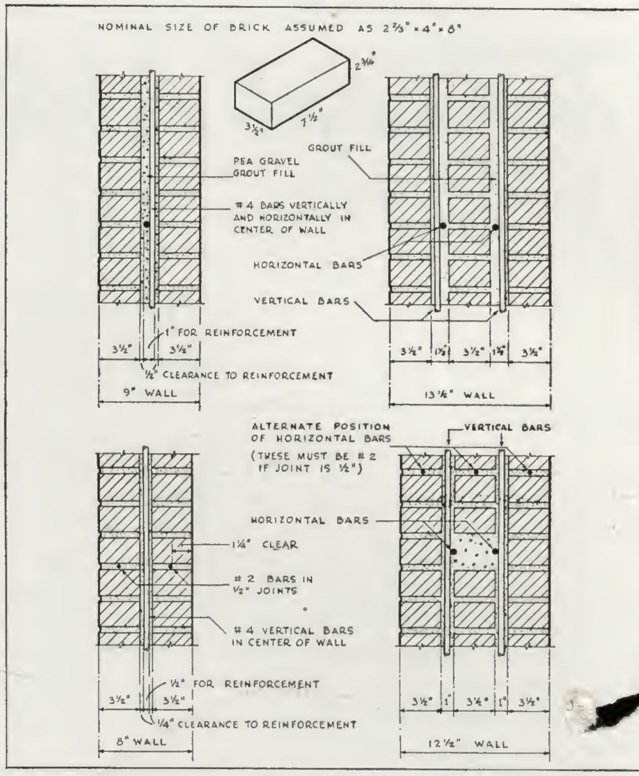

Fig. 2

larger than the diameter of the bars, so that there is at least ¼ in. of mortar or grout between the masonry units and the steel. Where both vertical and horizontal reinforcement is placed in a vertical interior joint, the joint thickness must be ½ in. larger than the sum of the diameters of the horizontal and vertical bars. The only exception to these rules is that ¼-in. diameter bars may be placed in ½-in. thick mortar joints.

These relationships of overall wall thicknesses to unit dimensions, bar diameters and required joint thicknesses are illustrated in Fig. 2. These details also illustrate how it is possible to reduce wall thickness by the omission of masonry units and the concentration of steel in the grout spaces left by leaving out those units. Another means of accomplishing this is by the use of split brick or soaps as shown in Fig. 3. In this example, it is also possible to place the steel nearer the outside surfaces of the section, thus increasing the effective depth.

Knowing the sizes of units to be used and being familiar with the relationship between bar sizes and joint widths, the designer will find that his freedom of design in RBM, insofar as establishing working design dimensions is concerned, will not be particularly hampered. In fact, once he has a grasp of those requirements, economical and structurally sound designs will be easily accomplished.

DESIGN CRITERIA

Although the principal reason that reinforced masonry has been used in lieu of unreinforced masonry in the past was to obtain greater resistance to lateral forces induced by winds, earthquakes or bomb blasts, RBM also has its place in designs where such lateral forces are not critical. It may be advantageous to use minimum or partially reinforced walls in order to take advantage of increased compressive strength and/or ratios of height and length to wall thickness. In many instances, the addition of reinforcement will permit the use of thinner wall sections and the resulting savings in cost will more than offset the additional cost of the reinforcement.

Today, however, there seems to be an increased interest on the part of engineers and architects in the design of structures to withstand lateral forces.

Lateral Forces. Lateral forces induced by wind, earthquake and bomb blast are dynamic in character. The time factor is most important, particularly for the earthquake and bomb blast. Although maximum velocity of the wind occurs in gusts of short duration, generally speaking, wind loading is more sustained than either earthquake or blast loading. The wind may strike a building from any direction and not necessarily normal to the wall surfaces. Blast forces are like wind in that they have a common point of origin. However, their time duration is much shorter — a matter of hundredths of a second. When a blast occurs in, on, or close to the ground, considerable ground motion may be transmitted to the structure as well as air disturbance. This fact, plus the impact effect and reversal of direction gives earthquake and blast reaction something in common.

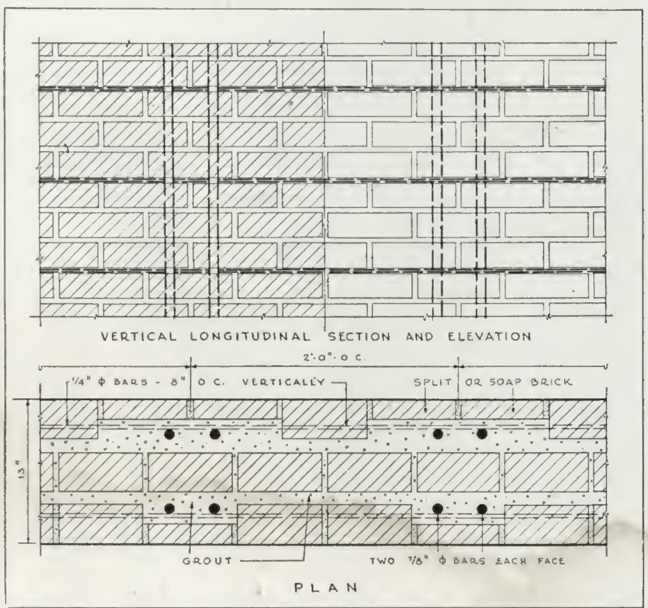

Fig. 3

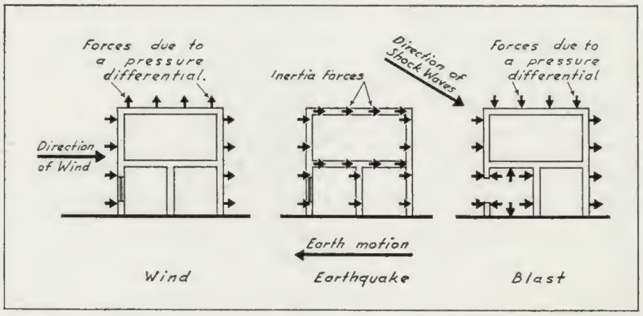

Fig. 4

In Fig. 4 is an over-simplified illustration of th[e] forces on a hypothetical structure from wind, e[...] quake and blast. No scale or quantit[...] son is intended.

The dynamic forces in[...] and blast are so comp[...] to use assumed [...] design. T[...] the e[...]valent static forces have been p[...] determined and that they are properly applied [...] design so that important details, stress paths, conn[...] tions, etc., can be provided.

It is never necessary that mo[...] three mentioned lateral f[...] combinations. The [...] one instant ar[...] calculated [...] forces i[...]

Rec[...] wind loads for buildings are inclu[...] Standard Minimum Design Loads in Buildings a[...] Other Structures, A58.1-1945. These pressures are based on a design wind velocity of 70 mph, corresponding roughly to a 5-min. average of 50 mph at 30 ft. above ground. In the absence of data from which to compute design pressures for a specific location and structure, it is recommended that the American Standard values be considered minimum.

The equivalent static forces resulting from earthquakes included in various codes differ materially. However, the suggested lateral force code, proposed by a joint committee of the San Francisco Section of the American Society of Civil Engineers and the Structural Engineers Association of Northern California, which is published in ASCE Transactions, Vol. 117, 1952, contains what are considered by many the most modern earthquake design minimum requirements for buildings in seismic areas.

The method of determining the static lateral forces, as proposed in this report and model code, takes into account not only the height of a structure but to some extent its dynamic properties, and it is based qualitatively, at least, on actual earthquake

records. This code is also unique in that the forces obtained are applied to a structure in a different manner than by other codes, in that they are based upon dynamic considerations.

The development of design criteria to resist bomb blast is in its early stages and many factors affecting design are still undetermined. Perhaps the most widely used criteria at the present time are contained in "Interim Guide for the Design of Buildings Exposed to Atomic Blast," published by the Federal Civil Defense Administration in June 1952.

This publication recommends, in addition to the 90 lb. per sq. ft. horizontal force and 70 lb. per sq. ft. vertical force on the structure as a whole, the design live loads, all intended to provide chance for survival (of structures) at ground zero":

The hollow cores sh... value of f′m shall be con... ultimate compressive load by ... hollow masonry units used.

When it is not possible to establish the ... of the ... walls, interior and exterior (except exterior ... shelter areas and units (psi ... expected and not more th... mortar is used. Such ass... exceed a value of 1500 psi nor ...

	... vertically downward
	... psf upward
Walls, interior and exterior (except exterior shelter areas)	70 psf from either side
	150 psf from either side
	... psf downward

WORKING STRESSES FOR STEEL

The allowable stresses in the steel reinfor... used in RBM sh...

There are two basic concepts developing in regard to design for resistance to atomic bomb explosion. The first involves an effort to retain the structure as a unit without severe damage to itself or to its contents. The second involves the use of "frangible" walls which will be reduced to small bits and thus not only absorb some energy but greatly reduce the amount of lateral force the remaining structural framework has to resist. Obviously, such design implies that the materials and occupants of the building are either expendable or will be protected in underground or other special smaller structures built within or within close proximity to the major structure.

CONCLUSION

This is the third in a series of Technical Notes Bulletins on the general subject of Reinforced Brick Masonry. As in any subject as comprehensive as this, it is impossible to do more than to merely give a brief introduction to the subject in a bulletin limited in space. For more complete information, including design data and details of construction, you are referred to the manual, Reinforced Brick Masonry and Lateral Force Design, by Plummer and Blume, published in 1953 by the Structural Clay Products Institute.